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TANK CAR THERMAL RESPONSE ANALYSIS: VOLUME 7

POOL FIRE - FLARE INTERACTIONS

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17. Abstract

A series of tests was performed to determine the effect of a high-velocity propane jet on the heat flux to a cylindrical surface within a pool fire.

Total heat flux to a cylindrical surface was measured using a specially designed calorimeter as well as a Hy-cal radiometer.

The measurements indicated that the propane flare did not significant affect the heat transfer to the calorimeter immersed in the pool fire.

Radiative interchange factors between a pool fire and a cylinder and a propane flare and a cylinder have been calculated by numerical integration.

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17. Resume

Ce rapport rend compte de la batterie d'essais visant à déterminer l'effet d'un jet de propane en feu sur les échanges thermiques d'une surface cylindrique plongée dans des flammes enveloppantes.

Le flux thermique total a été mesuré à l'aide d'un calorimètre conçu exprès et d'un radiomètre Hy-Cal.

Les essais ont montré que l'effet torche du propane ne modifie pas sensiblement les flux thermiques mesurés par le calorimètre plongé dans les flammes enveloppantes.

Par intégration numérique, les chercheurs ont calculé l'indice d'échange thermique par rayonnement entre les flammes enveloppantes et le cylindre, d'une part et, d'autre part, entre celui-ci et le jet de propane en feu.

18. Mots-clés	19. Diffusion
Accidents, BLEVE, ébullition, flammes enveloppantes, propane, rail, wagon-citerne, comportement thermique, protection	**Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.**

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A series of tests were performed to determine the effect of a high velocity propane jet flare on the heat flux to a cylindrical surface within a pool fire.

Three steel pans of 1 ft, 2 ft, and 3 ft diameters were used to contain the pool fire.

Two calorimeters of 0.25 in and 1 in diameters were placed in the pool fire at different positions (Figures I and II in the Appendix). The tops of the calorimeters were level with the propane nozzle tip which was 3 in above the pool surface. The rate of heat transfer to the calorimeters was determined by the increase in enthalpy of the water passing through the calorimeters. A sample calculation of the heat flux is presented in the Appendix.

A water cooled propane burner was placed close to the center of the pan. The nozzle of the burner is removable and the appropriate size nozzle is used for the corresponding size pan. A calibrated rotameter was used to measure the propane flow rate.

In experiments 4 to 6, a radiometer was placed near the center of the pan to measure the local heat flux in the fire. The top of the radiometer was 3 in above the pool surface.

Readings were taken on the calorimeter and the radiometer with a pool fire alone and with the propane flare operating within the pool fire. This gives a direct comparison of the total flux to the calorimeter and the radiometer with the

propane flare operating and not operating.

A summary of the results of the tests are presented in Table 1. Results of tests 1 to 4 indicate that there was an increase of 1 to 22% in heat flux to the 1 in diameter calorimeter with the addition of the propane flare to the pool fire, while test 5 showed a drop of 1.75% in heat flux with the propane flare operating.

For the 0.25 in diameter calorimeter, most of the tests showed a drop in heat flux in the range of 1 to 11% with the propane flare in addition to the pool fire. Only test #1 showed an increase of 6.5% in the heat flux with the propane flare operating within the pool fire.

Heat flux measured by the radiometer were available in tests #4 and 5. Test #4 indicated a 5% drop in heat flux whereas test #5 showed a slight increase of 1.10% after the propane flare was applied to the system. The data indicate that the propane flare does not substantially alter the heat flux to the calorimeter or radiometer for the conditions under which the test was conducted.

Test #6 was performed with a 3 ft diameter pan. It was found that within a few minutes after starting the propanol fire, the heat released from the pool fire caused the laboratory ceiling temperature to exceed the maximum allowed limit. The experiment was terminated before any meaningful data could be collected as the system was still in a transient state. It is proposed that the experiment with the 3 ft diameter pan be performed outdoors next spring.

TABLE 1

Heat Flux to Calorimeters and Radiometer in Proposal Pool Fire and Propane Flare Interaction Studies

Diameter of calorimeter = 1"							
Test #	Pan Size (ft)	Heat Flux Pool Fire (kw/m^2)	Heat Flux, Pool Fire & Propane Flare (kw/m^2)	% Change in Heat Flux	(SCFM) Propane Flow Rate	(SCFM) Target Propane Flow Rate	Water Flow Rate (kg/s)
1*	1	31.42	38.3	+22%	0.487	3.85	2.63×10^{-3}
2*	1	61.37	66.31	+ 8%	0.487	3.85	2.63×10^{-3}
3*	1	66.14	67.76	+ 2%	0.487	3.85	2.63×10^{-3}
4**	1	53.69	54.21	+ 1%	3.3	3.85	1.88×10^{-3}
5**	2	25.73	25.28	- 1.75%	6.84	15.48	5.47×10^{-3}

Diameter of calorimeter = 0.25"							
Test #	Pan Size (ft)	Heat Flux Pool Fire (kw/m^2)	Heat Flux, Pool Fire & Propane Flare (kw/m^2)	% Change in Heat Flux	(SCFM) Propane Flow Rate	(SCFM) Target Propane Flow Rate	Water Flow Rate (kg/s)
1*	1	46.63	49.68	+ 6.5%	0.487	3.85	2.03×10^{-3}
2*	1	79.76	75.68	- 5%	0.487	3.85	1.73×10^{-3}
3*	1	88.06	87.25	- 1%	0.487	3.85	1.75×10^{-3}
4**	1	-- ***	-- ***		3.3	3.85	2.07×10^{-3}
5**	2	59.29	52.63	-11%	6.84	15.48	2.47×10^{-3}

Radiometer						
Test #	Pan Size (ft)	Heat Flux Pool Fire (kw/m^2)	Heat Flux, Pool Fire & Propane Flare (kw/m^2)	% Change in Heat Flux	(SCFM) Propane Flow Rate	(SCFM) Target Propane Flow Rate
4	1	23.82	22.57	-5.27%	3.3	3.85
5	2	53.21	53.80	+1.10%	6.84	15.48

* See Figure I in Appendix for positions of the equipments in the pool fire.

** See Figure II in Appendix for positions of the equipments in the pool fire.

*** See Table II in Appendix for experimental data.

APPENDIX

Data needed for the calculation of the enthalpy change of the water passing through the calorimeters were:

1) Temperatures of the water going into and leaving the calorimeters.
2) Water flow rate.

Water was allowed to flow through a center tube into the calorimeter and back out through a concentric annulus. The temperature change of the water was measured with thermocouples over a length of 4 in of the calorimeter. There is only one thermocouple installed in the concentric annulus for measuring the hot water leaving the system. The calorimeter was rotated during the experiments to have the thermocouple at four different positions. The average of the four temperatures taken was used to calculate the enthalpy change of the water.

The water flow rate to the calorimeter was measured by a calibrated flow meter.

SAMPLE CALCULATION

q/A = $(\dot{m}\ Cp\ \Delta T)/A$

q/A = Heat flux per unit outside surface area of the calorimeter (kw/m^2)

$\dot{m}$ = Water mass flow rate (kg/s)

Cp = Heat capacity of the water = 4.18 kJ/kg

ΔT = Temperature change of the water

A = Exposed outside surface area of the calorimeter

$$A = \frac{\pi D^2}{4} + \pi DL$$

For 1 in diameter calorimeter,

$L = 4$ in

$D = 1$ in

$A = 8.62 \times 10^{-3} m^2$

For 0.25 in diameter calorimeter

$L = 4$ in

$D = 0.25$ in

$A = 2.06 \times 10^{-3} m^2$

For Test #5

Calorimeter diameter = 1 in

$\dot{m}$ = density of water x volumetric flow rate of water

$$= 1000 \frac{kg}{m^3} \times \left(113 \frac{cm^3}{min} \times \frac{1\ m^3}{10^6 cm^3} \times \frac{1\ min}{60\ sec}\right)$$

$$= 1.88 \times 10^{-3}\ kg/sec$$

$\Delta T = 58.89$

$q/A = 53.69\ kw/m^2$

TABLE II

Experimental Results for Test #4

Calorimeter diameter = 0.25 in

Pool diameter = 1 ft

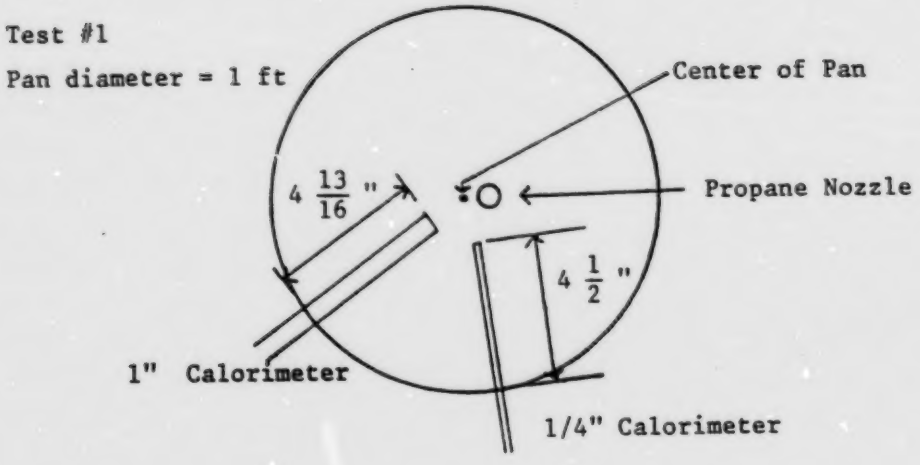
Water flow rate = 2.07×10^{-3} kg/s

Propane nozzle diameter = 3/32 in

Propane flow rate = 3.3 scfm

Thermocouple Positions	Pool Fire ΔT (°C)	Pool Fire with Propane Flare ΔT (°C)
1	17.5	17
2	21.5	20.8
3	22.2	22.93
4	--	--

The thermocouple was damaged at position 4. Thus an average of the temperature changes was not obtained for the calculation of the increase in enthalpy of the water.



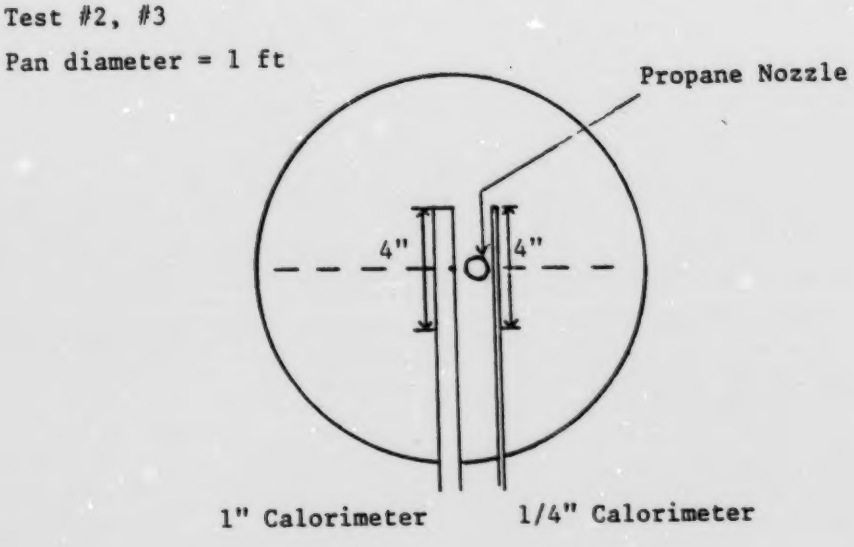


FIGURE II: Top View of the Positions of the Equipments in the Pool Fire for Tests 1 to 3.

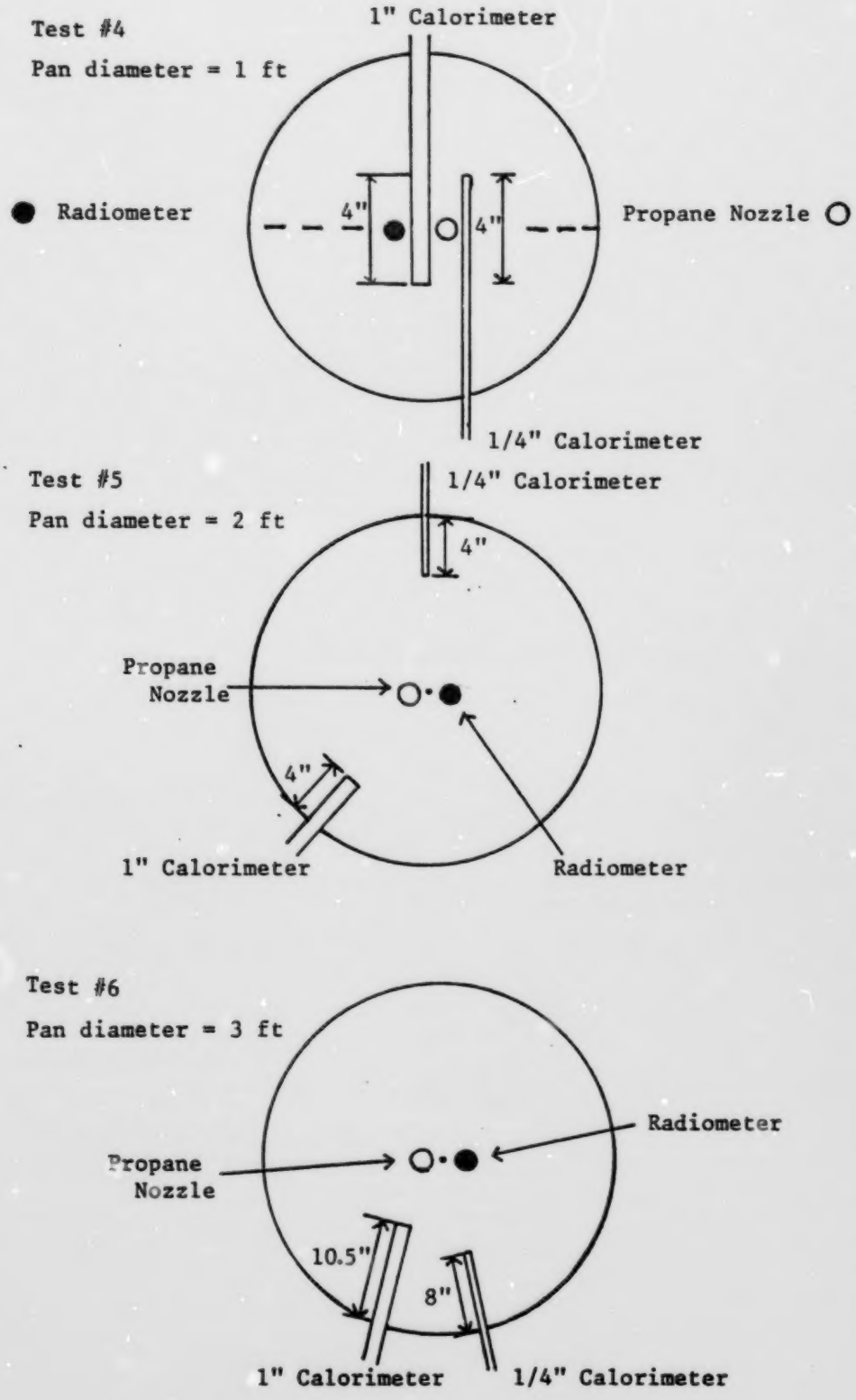


FIGURE II: Top View of the Positions of the Equipments in the Pool Fire for Tests 4 to 6.